

REPORT DOCUMENTATION PAGE

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MEMORANDUM FOR PRS (In-House Publication)

FROM: PROI (TI) (STINFO)

04 Dec 2000

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-2000-231
Hawkins, T., "Advanced Propellants"

Visit by Swedish Diplomats to AFRL (AFRL/Edwards, 05 Dec 2000)

(Statement A)

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement, b.) military/national critical technology, c.) export controls or distribution restrictions, d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.

Comments:

Signature _____ Date _____

2. This request has been reviewed by the Public Affairs Office for: a.) appropriateness for public release and/or b) possible higher headquarters review.

Comments:

Signature _____ **Date** _____

3. This request has been reviewed by the STINFO for: a.) changes if approved as amended, b) appropriateness of references, if applicable; and c.) format and completion of meeting clearance form if required

Comments: _____

• 44 •

Signature _____ Date _____

4. This request has been reviewed by PR for: a.) technical accuracy, b.) appropriateness for audience, c.) appropriateness of distribution statement, d.) technical sensitivity and economic sensitivity, e.) military/national critical technology, and f.) data rights and patentability

Comments:

APPROVED/APPROVED AS AMENDED/DISAPPROVED

PHILIP A. KESSEL

Date

Technical Advisor

Propulsion Science and Advanced Concepts Division

ADVANCED PROPELLANTS

5 December 2000



Dr. Tom Hawkins
Sr Research Chemist
Air Force Research Laboratory



Problem



- Low Performance of SOTA Propellant
 - Low D⁺Isp
- Increased Operations Costs:
 - Carcinogenic Vapor (Respiratory Route)
 - Dermal Toxicity
 - Strong Reducing Agent
 - Flammable (LEL = 4.7%, UEL = 100%)
- On-Orbit Propulsion Systems Affected
 - | System | Mission |
|-----------|------------------|
| FitSatCom | Military Comm |
| STARDUST | Deep Space Probe |
| INTELSAT | Commercial Comm |
| HEAO-B | X-Ray Astronomy |
 - Hundreds of Satellites Use Hydrazine for RCS & ACS

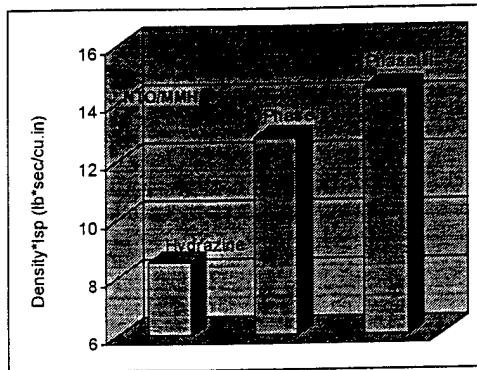




Monopropellant Performance Objectives



- Increase Density Isp of New Monopropellants for IHPPT Demonstration:
50% by 2005
>70% by 2010
- New Monopropellants to Have Reduced Toxicity- Allowing Operations w/o SCAPE-suited Crews



USAF is Lead for IHPPT Monopropellant Development



Desirable Monopropellant Properties



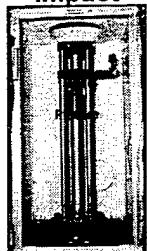
Characteristic	Objective
Density Isp [300 psi-vac; exp=50]	>70 % (Over SOTA)
Vapor Toxicity	Does Not Require SCBA
Carbon Content	No Solid Carbon Forms in Theoretical Exhaust
Melting Point	< 2°C
Detonability [NOL Card Gap]	Class 1.3; (Prefer 24 Cards Maximum (E ₅₀))
Impact Sensitivity [Drop Weight]	20 kg-cm Minimum (E ₅₀)
Adiabatic Compression [U-Tube Test]	No Explosive Decomposition (Pressure Ratio of 35)
Thermal Stability	< 2% by wt. Decomposition for 48 hrs at 75 °C
Critical Diameter	No Propagation in Lines of < 0.75 inch Diameter



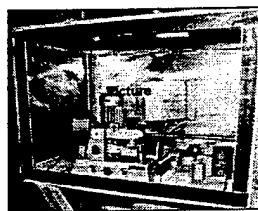
Ingredient/Propellant Testing



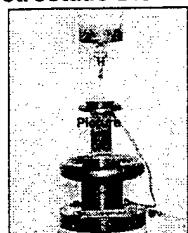
Impact



Friction



Electrostatic Discharge



Thermal

48 Hours

75 C

$\Delta T < 3C$
 $\Delta W < 2\%$

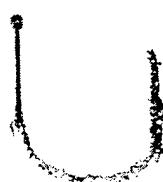


Adiabatic Compressibility

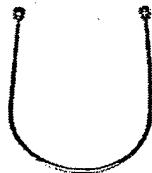


- Designed/Constructed Apparatus in FY00

- Propellant Sensitive to Rapid Compression



- Desired Result:
Insensitive to Rapid Compression



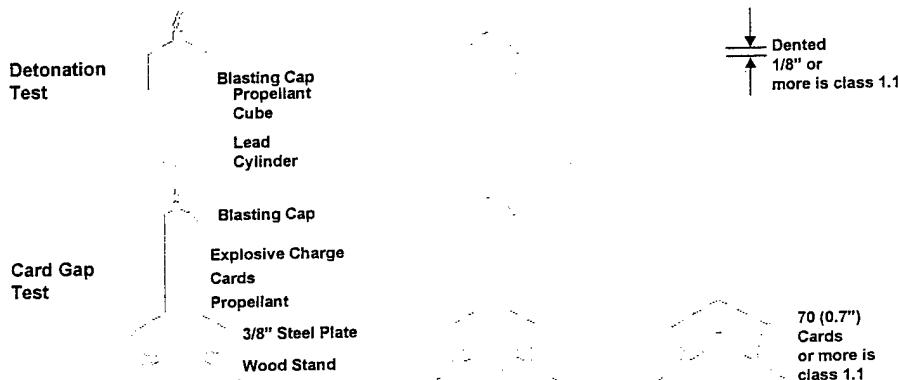


Propellant Testing

Shock to Detonation Tests



- All current solid rocket propellants are divided into two hazard classifications (1.1 or 1.3)
- Two tests are used to distinguish between classes 1.1 and 1.3.



R&D Strategy For Reduced Toxicity Monopropellants



Technical Challenges

- High Toxicity and Vapor Pressure of N_2H_4 Creates High Costs
- Performance Limited by Low Energy Density (8.4 lb_s/in³)
 - Need 14.4 lb_s/in³ by 2010
- Highly Ionic Solutions Tend to Have High Melting Points

Approaches

- Use Ionic Compounds with Extremely Low Vapor Pressures and Structures of Reduced Toxicity versus Hydrazine
- Target Energetic Structures Which Confer High Isp
 - High N Content Cations
 - Anions (e.g., $\text{C}(\text{NO}_2)_3^-$, NO_3^- , $\text{N}(\text{NO}_2)_2^-$)
- Employ Miscible and Low Melt Point Components



PHASE II Monopropellant



ACCOMPLISHMENT

Synthesis/Delivery of 12 high-N salt compounds for additional toxicological screening at AFRL/HEST

Evaluated monopropellant (Swedish Space Corp)

Produced liquid salt-type propellant for successful thruster test

SIGNIFICANCE

- Additional toxicity data on new propellants/compounds
- Supports development of QSAR for new propellant molecules' toxicity

- Has Phase II performance
- High solution miscibility temperature with hazardous solid residue

- Catalytic ignition verified
- Spurs hardware development
- Patent issues being worked



Monopropellant Properties



Properties	AFN1	AFN2	Hydrazine
Density, g/cc	1.43	1.46	1.01
Viscosity, cp	8.6	23.1	0.97
Chamber Temp. (Theoretical), K	2070	2083	883
Carbon Content of Exhaust; (b)	none	none	none
Impact Sensitivity*, kg-cm (5 negatives)	>200	60	>200
Friction Sensitivity, N (5 negatives)	318	300	>371
NOL Card Gap (at 69 Cards)	negative	negative	negative
Thermal Stability, %wt loss/48hr, 75°C	<2.0	<2.0	(<0.1)
Melt Point, C	5 (c)	<22	1

a: Theoretical, calculated with 300psi chamber pressure, exhaust to vacuum, 50/1 expansion

b: as soot or solid carbon (by theoretical computation)

c: by DSC; melt transition was broad, melt peak reported

*: For reference, n-propyl nitrate had an impact sensitivity of 8 kg-cm

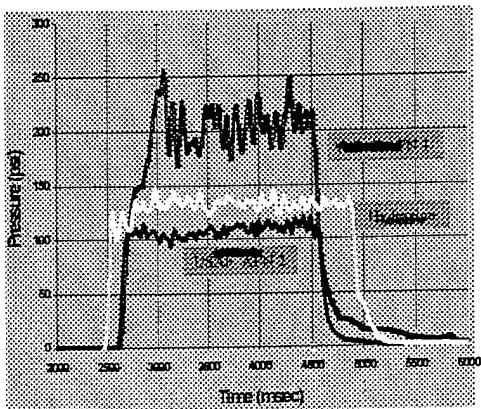
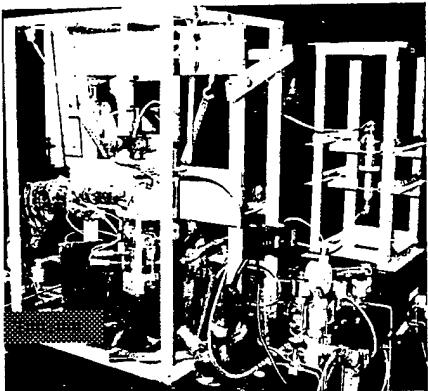
**AFN-Based Propellants Display Acceptable
Safety/Sensitivity Properties For Continued Development**



Monopropellant Thruster Testing



Monopropellant Thrust Stand



AFRL Fabricated Thruster and Initiated Testing



Catalyst Material Development



Contract Program Objectives

- SELECT CANDIDATE HIGH TEMPERATURE MATERIALS SUITABLE FOR CATALYTIC COMBUSTION OF AFRL MONOPROPELLANT
- MANUFACTURE AND SCREEN CATALYST/THERMAL BED SAMPLES
- EVALUATE PERFORMANCE OF DOWNSSELECTED CATALYSTS IN THRUSTER FIRINGS WITH AFRL MONOPROPELLANT



Monolithic Catalyst Bed

AFRL Collaboration Activity in FY01

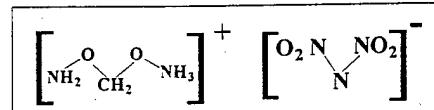
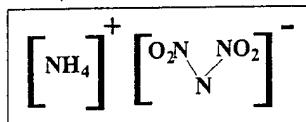
- EVALUATES CATALYST MATERIALS
- SUPPLIES PROPELLANT/COMPOUNDS FOR CATALYST EVALUATION



PHASE III MONOPROPELLANT Ingredient R&D



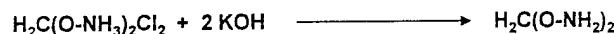
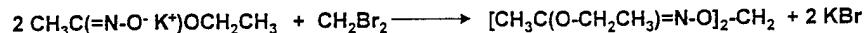
- Synthesizing/Evaluating dinitramide-based salts
- Many such salts (or salt-based monopropellants) exhibit 'challenging' safety properties
 - Performed evaluations with ADN and MBO salts



Methylene bisoxamine $\text{H}_2\text{C}(-\text{ONH}_2)_2$



Dr. C.S. McDowell et.al. original work published as U.S. patents in 1973, in which the detailed synthesis of MBO selected salts



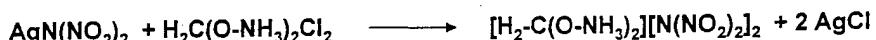


MBO bis(dinitramide) [H₂-C(O-NH₃)₂][N(NO₂)₂]₂



- Russians apparently synthesized through one or two routes:

- Metathesis with silver salts:



- Or, ion exchange:



- Reported (1995) as a colorless oil with a melting point of 20° C.



Dinitramide Salts of MBO



USAF production via cation exchange / neutralization



Bis-dinitramide Salt:

Appearance: White crystals

M.P. 95° C

Impact: < 5 kg-cm (detonated with a light hammer blow)

DSC Exotherm: 103 °C

Mono-dinitramide Salt:

Appearance: White crystals

M.P. 96° C

Impact: 12 kg-cm (very friction sensitive)

DSC Exotherm: 119 °C



High Performance Monopropellants -Summary-



- Continue work in monopropellant development & characterization
 - Promising, new approaches
 - Incorporating high energy density molecules
 - Encouraging initial propellant properties
 - Performance potential meets/exceeds bipropellant
 - Simpler, lighter propulsion system
 - Critical work remains
 - Stability, material compatibility, rheology
 - Propellant ignition , high temperature catalyst/materials
 - Teamed with industry

Work with Industry for Successful Technology Demonstration